

# Synomonal effect of nine varieties and one culture of rice on *Trichogramma japonicum* Ashmead and *Trichogramma chilonis* (Ishii) (Hymenoptera: Trichogrammatidae)

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**Abstract:** Bioassays of the hexane extracts of nine varieties *viz.*, Pusa Sugandh-2, Pusa Basmati-1, Pusa-2511, Pusa Basmati-370, Pusa-1077, Karnal Local, PRR-78, Jaya, Pusa-1238 and one culture of rice, Culture No. 34 in vegetative and flowering phase were carried out in Petri dish, to observe their synomonal effect on mean parasitoid activity index (PAI) and mean percent parasitism by *Trichogramma japonicum*, Ashmead and *Trichogramma chilonis* (Ishii). The hexane extracts of different rice varieties were subjected to gas liquid chromatography to determine the saturated hydrocarbons. Among these, leaf extracts from variety Pusa Sugandh-2 elicited maximum response in vegetative phase for both the parasitoids by way of mean percent parasitism. Whereas in flowering phase variety Pusa Basmati-1 elicited maximum mean percent parasitism. Gas liquid chromatography of the leaf extracts from vegetative phase revealed that Pusa Sugandh-2 had two favorable hydrocarbons pentacosane (C<sub>25</sub>) and nonacosane (C<sub>29</sub>). Gas liquid chromatography of leaf extract from flowering stage also revealed that Pusa Basmati-1 had three favorable hydrocarbons *viz.*, pentacosane (C<sub>25</sub>), hexacosane (C<sub>26</sub>) and nonacosane (C<sub>29</sub>) which could be ascribed to the highest response elicited by these varieties.

**Key words:** *Trichogramma japonicum*; *Trichogramma chilonis*; synomone; parasitoid; rice

## 1 INTRODUCTION

Behavioural manipulation of natural enemies of insect pest in relation to their environment is often required to get a higher level of success in insect pest management through increased parasitism or predation. In this process, proper understanding of the behaviour of the natural enemies in relation to their host or prey and habitat (plants) is important. Plants contain a complex array of diverse, non-nutritional, volatile, secondary compounds called as semiochemicals, mediating interactions between host plants, pest insects and natural enemies, are of significance in biological control (Ahmad *et al.*, 2004). Use of these semiochemicals, especially, the synomones released by host plants and the kairomones released by host insects or host by products are of significance in biological control. Among the egg parasitoids, the genus *Trichogramma* (Hymenoptera: Trichogrammatidae) heads the list and has received most attention because of its importance in biological control (King *et al.*, 1985; Yadav *et al.*, 2002). Trichogrammatids are

polyphagous egg parasitoids against many potential lepidopterous pests of different crops in many countries (Stinner, 1977). Many Trichogrammatids are found to show varietal preference for different varieties of host plants, due to the presence of favourable synomonal sources (Hagen, 1986). The response of the parasitoids in relations to its foraging behaviour varies depending on the growth stage of the plants (Romeis *et al.*, 1997). Therefore, the bioassays were carried out to elucidate the synomonal effect of leaf extracts from nine *viz.*, Pusa Sugandh-2, Pusa Basmati-1, Pusa-2511, Pusa Basmati-370, Pusa-1077, Karnal Local, PRR-78, Jaya, Pusa-1238 and one culture, Culture No. 34 of rice obtained from vegetative and flowering phase, on *Trichogramma japonicum* Ashmead and *T. chilonis* (Ishii). Hydrocarbons present in host plants were found to act as synomones for different species of *Trichogramma* in different crop ecosystems (Yadav *et al.*, 2002). Therefore in the present study the hexane leaf extracts (used for bioassay studies) were also analyzed through gas liquid chromatography to determine the saturated hydrocarbons present in them to understand the synomonal interaction.

## 2 MATERIALS AND METHODS

### 2.1 Insects

Isofemale lines of the egg parasitoids (Trichogrammatids) and nucleus stock of the host insects *Corcyra cephalonica* Stainton (Lepidoptera, Galleriidae) were taken out of the cultures maintained at the Biological Control Laboratory of the Division of Entomology, Indian Agricultural Research Institute, New Delhi-12. (India) Rice meal moth, *C. cephalonica* was reared using crushed sorghum grains sterilized at 150°C for 1 h as larval feed in a closed type rearing cage as described by Paul and Sreekumar (1998). Cleaned eggs were used for maintaining the culture of *C. cephalonica* as well as rearing the egg parasitoids used in the present studies, according to the need.

Cultures of the selected Trichogrammatids were developed from a single pair. The egg parasitoids were reared at  $26 \pm 1^\circ\text{C}$  and  $65\% \pm 5\%$  relative humidity, by offering 0 – 24 h old UV sterilized eggs of *C. cephalonica* glued in a single layer on paper egg card using gum arabic in glass vials of 10 cm  $\times$  2.5 cm size.

### 2.2 Leaf extracts preparation

Nine rice varieties *viz.*, Pusa Sugandh-2, Pusa Basmati-1, Pusa-2511, Pusa Basmati-370, Pusa-1077, Karnal Local, PRR-78, Jaya and Pusa-1238, and one culture, Culture No. 34 of rice were collected during vegetative and flowering phase of the crop from the rice fields of the Division of Genetics, Indian Agricultural Research Institute, New Delhi-12, (India) for preparation of plant extracts for bioassays and gas liquid chromatography studies. Two leaf samples of each variety (having three replications), one during vegetative phase and one during flowering phase were collected, washed with water, air dried and soaked overnight in hexane. The filtrate was kept in sodium sulphate for 1 h, and passed through silica gel column. The extract was then distilled at 60 – 70°C in a water bath. It was then rinsed with hexane and taken out in a small tube and evaporated completely by keeping the tube in a water bath. This was then used both for gas liquid chromatography and bioassay studies by adding appropriate quantity of distilled hexane. The concentrations used in bioassay were  $C_1 = 25\,000\text{ mg/L}$ ;  $C_2 = 50\,000\text{ mg/L}$ ;  $C_3 = 100\,000\text{ mg/L}$ ;  $C_4 = 200\,000\text{ mg/L}$  and  $C_5 = 400\,000\text{ mg/L}$ .

### 2.3 Analysis of leaf extracts

Leaf extracts were analysed for the presence of saturated hydrocarbons by gas liquid chromatography fitted with a flame ionization detector (FID) and capillary column (VF-1mS, 15 m) packed on Varian 3900. The operating condition used were column temperature 100°C to 250°C @  $10^\circ\text{C} / \text{min}$  and injector and detector temperature was 300°C. Nitrogen was used, as a carrier gas with a flow rate of

20 mL/min. Injection volume was 1  $\mu\text{L}$ . The hydrocarbons were identified, by comparing with the standards obtained from Sigma Aldrich USA. For calculating the concentration of unknown saturated hydrocarbon, the following formula was used:

Concentration of unknown saturated hydrocarbon =  $(\text{Area of unknown saturated hydrocarbon} / \text{Area of known saturated hydrocarbon}) \times \text{Concentration of known saturated hydrocarbon}$ .

### 2.4 Bioassay protocol

Bioassays studies were conducted under laboratory conditions at  $26 \pm 2^\circ\text{C}$  and  $65\% \pm 5\%$  RH. The studies were carried out in glass petri dishes of 150 mm  $\times$  15 mm size on a laboratory table with 40 W overhead fluorescent tubes as a source of light. In experimental arena light density was 160 lx. The procedure adopted was similar to that described by Padamavathi and Paul (1998). In each Petri dish, 10 healthy, 0 – 24 h old, fed, mated and fast reviving females of *Trichogramma* were released at the center of each Petri dish containing treated egg cards. Each Petri dish was considered as a replication and six such replications were maintained. The parasitoids were allowed to search in the experimental arena for a total period of 45 min from the time of recovery number of parasitoids that visited the egg card was counted at a 5 min interval which is referred here in after as the parasitoid activity index (PAI). After 45 min, the parasitoids were removed carefully from each egg card and these cards were kept individually in homeopathic vials (1 dram size) for development at  $26 \pm 2^\circ\text{C}$  and  $65\% \pm 5\%$  RH. Mean parasitoid activity index (PAI) and mean percent parasitism were recorded.

### 2.5 Statistical analysis

PAI and mean percent parasitism were analysed by ANOVA (Gomez and Gomez, 1968), using Sigma Stat 2.0 developed by Jandel Corporation, San Rafael, CA.

## 3 RESULTS

### 3.1 Synomonal interaction in the vegetative period

The study showed that synomonal interaction of egg parasitoid *T. japonicum* and nine varieties and one culture of rice revealed that variety Pusa Sugandh-2 elicited maximum responses from *T. japonicum* in vegetative phase by way of mean PAI and mean percent parasitism (5.81, 24.16) irrespective of all the concentrations tested. In variety Karnal Local, however, least PAI and mean percent parasitism (3.11, 8.50) was recorded (Table 1 and 3). In vegetative phase, response observed for *T. chilonis* revealed that Culture No. 34 elicited maximum response as evidenced by mean PAI (4.56) followed by Pusa Sugandh-2 (4.39). Least mean PAI was recorded for variety Karnal Local (2.11). Whereas variety Pusa Sugandh-2 elicited maximum responses from *T.*

chilonis in vegetative phase by way of mean percent parasitism (23.24). Least mean percent parasitism was recorded for variety Jaya (4.81) (Table 2 and 4).

**Table 1** Synomonal effect of hexane leaf extract of nine varieties and one culture of rice on mean parasitoid activity index (PAI) of *Trichogramma japonicum* in vegetative phase

Varieties	Concentrations of hexane leaf extract (mg/L)						Mean
	25 000	50 000	100 000	200 000	400 000	0 (Hexane)	
Pusa Basmati-1	3.67 ± 1.34	7.33 ± 1.09	2.17 ± 1.54	2.83 ± 1.20	3.17 ± 1.34	3.83 ± 1.54	3.83 ± 0.55
Pusa Basmati-2511	2.17 ± 1.54	3.50 ± 1.34	2.33 ± 1.54	6.17 ± 1.20	5.00 ± 1.34	0.50 ± 1.54	3.28 ± 0.54
Pusa Basmati-177	3.67 ± 1.54	7.50 ± 1.20	6.33 ± 1.34	7.670 ± 1.09	2.17 ± 1.54	4.33 ± 1.20	5.28 ± 0.58
Pusa Basmati-370	4.83 ± 1.20	5.00 ± 1.34	3.83 ± 1.09	6.00 ± 1.20	6.50 ± 1.09	2.33 ± 1.34	4.75 ± 0.49
Pusa Sugandh-2	5.83 ± 1.09	8.33 ± 1.09	7.50 ± 1.20	7.50 ± 1.20	2.83 ± 1.89	2.83 ± 1.34	5.81 ± 0.54
Karnal Local	2.83 ± 1.34	1.83 ± 1.34	1.67 ± 1.34	4.33 ± 1.09	5.33 ± 1.54	2.67 ± 1.09	3.11 ± 0.53
Jaya	10.67 ± 1.09	6.50 ± 1.20	4.67 ± 1.09	3.50 ± 1.20	1.00 ± 1.54	1.50 ± 1.89	4.64 ± 0.56
Pusa Basmati-1238	4.67 ± 1.34	4.17 ± 1.34	3.50 ± 1.34	5.83 ± 1.20	6.00 ± 1.20	2.17 ± 1.54	4.39 ± 0.54
PRR-78	8.50 ± 1.09	5.00 ± 1.20	6.17 ± 1.34	3.33 ± 1.34	3.33 ± 1.34	2.33 ± 1.54	4.78 ± 0.54
Culture No. 34	1.17 ± 1.34	5.00 ± 1.09	3.33 ± 1.20	2.83 ± 1.34	5.83 ± 1.09	2.83 ± 1.20	3.50 ± 0.49

Values are mean of eight observations ± standard error. The same below

**Table 2** Synomonal effect of hexane leaf extract of nine varieties and one culture of rice on mean parasitoid activity index (PAI) of *Trichogramma chilonis* in vegetative phase

Varieties	Concentrations of hexane leaf extract (mg/L)						Mean
	25 000	50 000	100 000	200 000	400 000	0 (Hexane)	
Pusa Basmati-1	3.00 ± 1.21	2.50 ± 1.49	2.00 ± 1.21	6.33 ± 0.94	5.17 ± 1.05	1.17 ± 1.49	3.36 ± 0.51
Pusa Basmati-2511	0.17 ± 2.10	3.50 ± 0.94	5.33 ± 0.86	2.00 ± 1.05	3.33 ± 0.94	1.67 ± 0.94	2.67 ± 0.50
Pusa Basmati-177	7.50 ± 0.86	6.00 ± 0.94	2.50 ± 0.86	4.17 ± 1.05	2.67 ± 1.49	2.83 ± 0.86	4.28 ± 0.42
Pusa Basmati-370	3.50 ± 0.94	2.50 ± 1.49	5.50 ± 0.94	2.83 ± 0.86	6.83 ± 0.86	3.17 ± 0.86	4.06 ± 0.42
Pusa Sugandh-2	4.00 ± 0.86	6.00 ± 0.86	5.17 ± 0.86	5.33 ± 0.86	1.33 ± 2.10	4.50 ± 0.94	4.39 ± 0.48
Karnal Local	4.50 ± 1.05	1.00 ± 1.49	2.50 ± 0.94	2.50 ± 0.94	1.00 ± 1.49	1.17 ± 1.05	2.11 ± 0.48
Jaya	2.67 ± 0.86	2.83 ± 0.94	2.83 ± 1.05	1.00 ± 2.10	1.33 ± 1.49	2.33 ± 1.21	2.17 ± 0.55
Pusa Basmati-1238	3.33 ± 1.05	1.33 ± 1.21	1.50 ± 1.21	3.17 ± 1.05	2.67 ± 1.21	2.00 ± 1.21	2.33 ± 0.47
PRR-78	2.67 ± 0.94	2.17 ± 1.05	2.83 ± 1.05	2.67 ± 0.94	2.00 ± 0.86	1.83 ± 1.05	2.36 ± 0.40
Culture No. 34	4.00 ± 0.86	5.00 ± 0.86	4.50 ± 0.86	3.83 ± 0.86	4.33 ± 0.86	5.67 ± 0.88	4.56 ± 0.35

**Table 3** Synomonal effect of hexane leaf extract of nine varieties and one culture of rice on mean percent parasitism of *Trichogramma japonicum* in vegetative phase

Varieties	Concentrations of hexane leaf extract (mg/L)						Mean
	25 000	50 000	100 000	200 000	400 000	0 (Hexane)	
Pusa Basmati-1	12.78 ± 5.25	21.11 ± 4.29	8.89 ± 6.06	10.55 ± 4.70	9.44 ± 5.25	12.78 ± 6.06	12.59 ± 2.17
Pusa Basmati-2511	7.22 ± 6.06	15.00 ± 5.25	7.78 ± 6.06	20.56 ± 4.70	17.22 ± 5.25	1.11 ± 7.43	11.48 ± 2.39
Pusa Basmati-177	18.33 ± 6.06	21.67 ± 4.70	20.00 ± 4.29	26.11 ± 4.29	9.44 ± 4.29	10.55 ± 4.29	17.68 ± 1.92
Pusa Basmati-370	18.89 ± 4.70	17.22 ± 4.70	11.11 ± 4.29	19.44 ± 4.70	15.55 ± 4.29	18.89 ± 4.29	16.85 ± 1.84
Pusa Sugandh-2	12.22 ± 4.29	27.22 ± 4.29	27.78 ± 4.29	33.88 ± 4.29	31.66 ± 4.29	12.22 ± 6.06	24.16 ± 1.89
Karnal Local	5.55 ± 5.25	12.22 ± 5.25	7.17 ± 5.25	3.28 ± 7.43	6.11 ± 4.70	16.66 ± 4.29	8.50 ± 2.23
Jaya	12.22 ± 4.29	27.22 ± 4.29	15.55 ± 4.29	12.22 ± 4.29	6.67 ± 6.06	1.11 ± 10.50	12.50 ± 2.48
Pusa Basmati-1238	3.33 ± 7.43	20.00 ± 5.25	16.67 ± 5.25	13.89 ± 5.25	22.78 ± 7.43	26.66 ± 4.29	17.22 ± 2.42
PRR-78	8.33 ± 4.70	27.22 ± 4.29	23.33 ± 4.29	20.56 ± 4.70	9.44 ± 7.43	13.89 ± 5.25	17.13 ± 2.13
Culture No. 34	9.44 ± 6.06	2.78 ± 7.43	11.67 ± 4.29	11.66 ± 4.29	6.67 ± 6.06	18.89 ± 4.29	10.18 ± 2.26

**Table 4 Synomonal effect of hexane leaf extract of nine varieties and one culture of rice on mean percent parasitism of *Trichogramma chilonis* in vegetative phase**

Varieties	Concentrations of hexane leaf extract ( mg/L)						Mean
	25 000	50 000	100 000	200 000	400 000	0 ( Hexane )	
Pusa Basmati-1	8.89 ± 2.70	8.33 ± 2.70	5.55 ± 2.70	20.55 ± 2.70	16.66 ± 2.70	2.78 ± 2.74	10.46 ± 1.10
Pusa Basmati-2511	0.00 ± 4.68	13.89 ± 2.69	16.67 ± 2.70	4.44 ± 2.70	8.33 ± 2.74	3.89 ± 2.70	7.87 ± 1.10
Pusa Basmati-177	21.11 ± 2.70	16.66 ± 2.70	4.44 ± 2.70	13.33 ± 2.70	7.78 ± 2.70	5.00 ± 2.70	11.39 ± 1.10
Pusa Basmati-370	11.11 ± 2.70	7.22 ± 2.73	18.89 ± 2.70	8.89 ± 2.70	20.55 ± 2.69	10.00 ± 2.74	12.78 ± 1.10
Pusa Sugandh-2	29.44 ± 2.70	22.22 ± 2.70	41.66 ± 2.70	17.22 ± 2.70	7.22 ± 2.70	21.67 ± 2.70	23.24 ± 1.10
Karnal Local	15.00 ± 2.70	5.00 ± 2.70	10.00 ± 2.70	10.00 ± 2.70	2.78 ± 2.70	5.55 ± 2.71	8.05 ± 1.10
Jaya	8.33 ± 2.70	6.11 ± 2.70	1.11 ± 4.68	3.89 ± 2.67	3.33 ± 2.70	6.11 ± 2.70	4.81 ± 1.27
Pusa Basmati-1238	19.44 ± 2.70	15.00 ± 2.70	10.00 ± 2.70	7.22 ± 2.70	3.89 ± 2.70	4.44 ± 2.70	10 ± 1.10
PRR-78	13.33 ± 2.70	5.00 ± 2.72	10.55 ± 2.70	15.00 ± 2.70	2.22 ± 2.70	7.22 ± 2.70	8.89 ± 1.10
Culture No. 34	7.78 ± 2.70	8.89 ± 2.70	9.44 ± 2.70	6.67 ± 2.70	16.11 ± 2.70	8.89 ± 2.74	9.63 ± 1.10

### 3.2 Synomonal interaction in the flowering period

In the flowering phase synomonal interaction of egg parasitoid *T. japonicum* and selected rice varieties/ culture revealed that variety Pusa Basmati-1 registered highest mean PAI and mean percent parasitism (5.06 and 20.37) irrespective of the all concentrations tested (Table 5 and 7). Response observed for *T. chilonis* revealed that Culture No. 34, elicited maximum response

in flowering phase as evidenced by mean PAI (4.91) followed by Pusa Basmati-1 (4.47). Response from *T. chilonis* in flowering phase by way of mean percent parasitism (13.97) was noticed in Pusa Basmati-1. Least mean PAI was recorded for variety Pusa-2511 (1.75), whereas variety Karnal Local elicited least mean percent parasitism (Table 6 and 8).

**Table 5 Synomonal effect of hexane leaf extract of nine varieties and one culture of rice on mean parasitoid activity index of *Trichogramma japonicum* in flowering phase**

Varieties	Concentrations of hexane leaf extract ( mg/L)						Mean
	25 000	50 000	100 000	200 000	400 000	0 ( Hexane )	
Pusa Basmati-1	6.50 ± 0.79	5.50 ± 0.79	5.67 ± 0.79	6.67 ± 0.79	4.00 ± 0.88	2.00 ± 1.02	5.06 ± 0.35
Pusa Basmati-2511	4.17 ± 0.88	4.17 ± 1.02	3.67 ± 0.88	5.50 ± 0.79	6.67 ± 0.72	2.00 ± 1.02	4.36 ± 0.36
Pusa Basmati-177	4.50 ± 0.88	5.67 ± 0.79	5.33 ± 0.72	3.00 ± 1.02	2.00 ± 1.25	2.33 ± 0.88	3.81 ± 0.38
Pusa Basmati-370	5.00 ± 0.72	5.00 ± 0.88	2.33 ± 0.88	4.17 ± 1.25	3.00 ± 0.79	2.33 ± 1.02	3.64 ± 0.38
Pusa Sugandh-2	3.50 ± 0.79	4.33 ± 0.88	1.67 ± 1.25	2.17 ± 0.72	2.33 ± 1.02	0.83 ± 1.76	2.47 ± 0.46
Karnal Local	1.67 ± 0.79	2.00 ± 0.72	4.67 ± 0.72	5.50 ± 0.88	3.00 ± 1.02	1.00 ± 0.88	2.97 ± 0.34
Jaya	7.83 ± 0.72	7.33 ± 0.72	5.67 ± 0.88	2.67 ± 0.79	2.00 ± 0.88	1.50 ± 1.76	4.5 ± 0.42
Pusa Basmati-1238	5.17 ± 0.72	3.83 ± 1.02	4.00 ± 0.79	7.17 ± 0.79	5.33 ± 0.79	3.00 ± 0.79	4.75 ± 0.34
PRR-78	3.67 ± 0.72	4.67 ± 0.72	5.67 ± 0.79	3.17 ± 0.72	3.50 ± 1.02	1.50 ± 0.88	3.69 ± 0.33
Culture No. 34	1.17 ± 0.88	1.83 ± 1.02	1.50 ± 1.02	5.17 ± 0.88	4.00 ± 1.02	2.50 ± 0.88	2.69 ± 0.39

**Table 6 Synomonal effect of hexane leaf extract of nine varieties and one culture of rice on mean parasitoid activity index of *Trichogramma chilonis* in flowering phase**

Varieties	Concentrations of hexane leaf extract ( mg/L)						Mean
	25 000	50 000	100 000	200 000	400 000	0 ( Hexane )	
Pusa Basmati-1	5.00 ± 0.85	2.50 ± 1.35	4.33 ± 0.85	4.66 ± 0.85	7.33 ± 0.78	3.00 ± 1.10	4.47 ± 0.40
Pusa Basmati-2511	4.00 ± 1.10	2.50 ± 1.35	1.17 ± 1.35	3.83 ± 0.95	7.17 ± 0.78	2.00 ± 0.95	3.44 ± 0.45
Pusa Basmati-177	3.50 ± 1.10	5.00 ± 0.78	5.50 ± 0.85	4.00 ± 0.95	4.17 ± 1.10	3.67 ± 0.95	4.31 ± 0.39
Pusa Basmati-370	1.33 ± 1.35	1.17 ± 1.35	1.50 ± 1.10	2.83 ± 0.95	3.33 ± 0.95	0.33 ± 1.91	1.75 ± 0.54
Pusa Sugandh-2	2.83 ± 1.35	3.17 ± 0.95	6.00 ± 0.78	1.33 ± 0.95	0.83 ± 1.35	2.50 ± 1.35	2.78 ± 0.47
Karnal Local	3.00 ± 0.85	2.33 ± 0.85	2.67 ± 0.78	0.67 ± 1.35	2.33 ± 0.95	0.33 ± 1.91	1.89 ± 0.48
Jaya	3.33 ± 0.95	1.83 ± 1.35	0.83 ± 1.35	1.50 ± 1.35	1.67 ± 1.10	2.33 ± 1.10	1.83 ± 0.50
Pusa Basmati-1238	4.83 ± 0.85	4.17 ± 0.78	1.67 ± 0.85	3.00 ± 0.95	2.67 ± 0.95	1.83 ± 0.85	3.03 ± 0.36
PRR-78	2.83 ± 0.78	0.17 ± 1.91	2.67 ± 0.78	1.67 ± 0.85	4.00 ± 0.85	1.17 ± 1.35	2.08 ± 0.48
Culture No. 34	5.00 ± 0.85	2.50 ± 1.35	4.33 ± 0.85	4.66 ± 0.85	7.33 ± 0.78	3.00 ± 1.10	4.91 ± 0.34

**Table 7** Synomonal effect of hexane leaf extract of nine varieties and one culture of rice on mean percent parasitism of *Trichogramma japonicum* in flowering phase

Varieties	Concentrations of hexane leaf extract ( mg/L)						Mean
	25 000	50 000	100 000	200 000	400 000	0 (Hexane)	
Pusa Basmati-1	31.11 ± 5.10	22.22 ± 5.59	20.55 ± 5.10	25.00 ± 5.59	15.55 ± 6.25	7.78 ± 7.21	20.37 ± 2.39
Pusa Basmati-2511	13.89 ± 6.25	13.89 ± 7.21	12.22 ± 6.25	18.33 ± 5.59	22.78 ± 5.10	6.67 ± 7.21	14.63 ± 2.58
Pusa Basmati-177	15.00 ± 6.25	22.78 ± 5.59	18.89 ± 5.10	11.67 ± 7.21	5.55 ± 8.83	5.00 ± 7.21	13.15 ± 2.78
Pusa Basmati-370	21.11 ± 5.10	19.44 ± 6.25	11.67 ± 6.25	14.44 ± 6.25	13.33 ± 6.25	8.33 ± 7.21	14.72 ± 2.55
Pusa Sugandh-2	18.32 ± 5.10	20.00 ± 7.21	13.89 ± 7.21	6.11 ± 7.21	11.11 ± 7.21	5.00 ± 12.49	12.41 ± 3.29
Karnal Local	7.22 ± 5.59	8.33 ± 6.25	22.77 ± 5.10	20.00 ± 5.10	8.33 ± 7.21	5.00 ± 7.21	11.94 ± 2.51
Jaya	25.00 ± 5.10	22.78 ± 5.59	11.68 ± 6.25	5.00 ± 7.21	6.11 ± 7.21	5.56 ± 12.49	12.68 ± 3.15
Pusa Basmati-1238	15.00 ± 5.10	14.44 ± 7.21	8.33 ± 7.21	20.00 ± 5.59	12.78 ± 5.59	12.78 ± 6.25	13.89 ± 2.54
PRR-78	22.78 ± 5.10	18.33 ± 5.10	28.89 ± 5.10	17.77 ± 5.59	11.67 ± 6.25	3.33 ± 8.83	17.13 ± 2.51
Culture No. 34	3.33 ± 8.83	7.22 ± 7.21	6.11 ± 7.21	18.33 ± 5.10	10.00 ± 7.21	6.11 ± 6.25	8.53 ± 2.88

**Table 8** Synomonal effect of hexane leaf extract of nine varieties and one culture of rice on mean percent parasitism of *Trichogramma chilonis* in flowering phase

Varieties	Concentrations of hexane leaf extract ( mg/L)						Mean
	25 000	50 000	100 000	200 000	400 000	0 (Hexane)	
Pusa Basmati-1	15.55 ± 4.32	8.33 ± 6.11	14.44 ± 3.86	15.55 ± 3.86	21.66 ± 3.53	8.33 ± 4.99	13.99 ± 1.85
Pusa Basmati-2511	12.78 ± 4.99	8.33 ± 6.11	3.89 ± 6.11	15.55 ± 4.32	25.55 ± 3.53	6.66 ± 4.32	12.13 ± 2.04
Pusa Basmati-177	13.33 ± 4.99	15.55 ± 3.53	15.00 ± 3.86	12.22 ± 4.32	8.33 ± 4.99	7.22 ± 4.99	11.94 ± 1.83
Pusa Basmati-370	6.67 ± 3.86	6.11 ± 6.11	7.22 ± 3.86	12.22 ± 3.53	14.44 ± 3.86	1.11 ± 4.99	7.96 ± 1.82
Pusa Sugandh-2	10.56 ± 6.11	11.11 ± 3.53	18.33 ± 3.53	3.33 ± 4.32	3.89 ± 4.99	8.33 ± 8.64	9.25 ± 2.24
Karnal Local	10.55 ± 4.32	10.55 ± 4.32	5.00 ± 6.11	3.83 ± 4.32	8.33 ± 4.99	1.67 ± 6.11	6.66 ± 2.08
Jaya	11.11 ± 4.32	9.44 ± 4.99	8.33 ± 4.32	4.44 ± 4.32	5.00 ± 6.11	6.67 ± 4.99	7.50 ± 1.99
Pusa Basmati-1238	19.44 ± 3.86	11.66 ± 3.53	5.00 ± 4.32	10.55 ± 4.32	5.00 ± 4.99	5.00 ± 4.32	9.44 ± 1.73
PRR-78	12.22 ± 3.86	1.11 ± 8.64	5.55 ± 3.53	8.89 ± 3.86	13.33 ± 3.86	7.78 ± 4.99	8.15 ± 2.09
Culture No. 34	6.11 ± 4.99	11.67 ± 3.86	11.11 ± 4.32	15.55 ± 3.53	8.89 ± 4.32	12.78 ± 3.86	11.02 ± 1.7

### 3.3 Synomonal hydrocarbons from host plants

Gas liquid chromatograph of nine varieties and one culture of rice in vegetative and flowering phase revealed the presence of favourable as well as unfavorable saturated hydrocarbons ranging from C<sub>10</sub> to C<sub>30</sub> varying in number and concentration eliciting varied level of synomonal response from both the targeted Trichogrammatids. Gas liquid chromatograph of Pusa Sugandh-2, which showed maximum mean percent parasitism in vegetative phase revealed the presence of two favourable hydrocarbon pentacosane (C<sub>25</sub>) and nonacosane (C<sub>29</sub>) (Table 9). Gas liquid chromatography studies of Pusa Basmai-1, which is preferred variety in flowering phase) showed the presence of pentacosane (C<sub>25</sub>), hexacosane (C<sub>26</sub>), nonacosane (C<sub>29</sub>), heptadecane (C<sub>17</sub>), nonadecan (C<sub>19</sub>), heptacosane (C<sub>27</sub>), and triacontane (C<sub>30</sub>), among these pentacosane (C<sub>25</sub>), was the highest (Table 10).

## 4 DISCUSSION

Synomone produced by plants are reported to be very significant in eliciting host-seeking response in many natural enemies. Hendry *et al.* (1976), analysed five host plants of *Heliothis zea* (Boddie) to determine the presence of hydrocarbons acting as synomone for *T. evanescens* Westwood. They identified series of hydrocarbons present in host plants ranging from C<sub>21</sub> to C<sub>25</sub> in varying quantities. Nordlund *et al.* (1985) also studied the response of *T. pretiosum* Riley females to volatile synomones from tomato plants. It was observed that volatile synomones from tomato plants stimulated search behaviour in *T. pretiosum* resulting in increased rates of parasitism of eggs of the noctuid *H. zea* in both laboratory and field. In a Y-tube olfactometer, females of trichogrammatid were attracted by tomato volatiles. Hilker *et al.* (2002) studied the tritrophic interactions in two systems: (1) the elm (*Ulmus glabra* Huds.),

**Table 9 Hydrocarbon profile of nine varieties and one culture of rice in vegetative phase**

Hydrocarbon	Pusa Basmati-1	Pusa Basmati-2511	Pusa Basmati-1077	Pusa Basmati-370	Pusa Sugandh-2	Karnal Local	Jaya	Pusa Basmati-1238	PRR-78	Culture No. 34
Favourable										
Henicosane (C <sub>21</sub> )	ND	ND	ND	ND	ND	ND	ND	ND	162.10	ND
Docosane (C <sub>22</sub> )	ND	66.00	ND	ND	ND	ND	ND	ND	ND	84.77
Tricosane (C <sub>23</sub> )	ND	ND	ND	ND	ND	ND	ND	7 694.22	ND	ND
Pentacosane (C <sub>25</sub> )	3 930	838.26	1 091.28	1 429.44	764.95	185.01	103.24	5 908.31	413.40	31.25
Octacosane (C <sub>28</sub> )	49.00	16.00	ND	ND	ND	4.02	568.98	ND	1.88	ND
Nonacosane (C <sub>29</sub> )	891.90	ND	424.60	ND	165.88	85.12	ND	ND	63.18	40.41
Unfavorable										
Pentadecane (C <sub>15</sub> )	ND	ND	0.01	0.07	ND	ND	0.02	0.55	0.01	0.05
Eicosane (C <sub>20</sub> )	ND	ND	ND	38.40	ND	1.60	ND	6.07	0.59	776.23
Others										
Decane (C <sub>10</sub> )	ND	ND	ND	ND	ND	ND	0.02	ND	ND	ND
Undecane (C <sub>11</sub> )	ND	ND	0.03	ND	ND	ND	0.04	ND	ND	0.21
Dodecane (C <sub>12</sub> )	ND	ND	0.05	ND	ND	0.01	0.10	ND	ND	0.02
Tridecane (C <sub>13</sub> )	ND	ND	0.01	ND	ND	ND	0.02	ND	ND	0.04
Tetradecane (C <sub>14</sub> )	ND	ND	0.01	ND	ND	ND	0.01	ND	ND	0.01
Hexadecane (C <sub>16</sub> )	ND	ND	0.01	ND	ND	ND	0.02	0.01	0.01	0.01
Heptadecane (C <sub>17</sub> )	235.60	ND	ND	ND	ND	0.01	ND	0.05	0.19	ND
Octadecane (C <sub>18</sub> )	ND	ND	ND	ND	98.10	ND	ND	ND	ND	ND
Nonadecane (C <sub>19</sub> )	ND	175.40	ND	ND	ND	ND	ND	ND	1.73	ND
Heptacosane (C <sub>27</sub> )	1 642.00	1 317.00	ND	ND	260.22	ND	ND	ND	ND	115.45
triacontane (C <sub>30</sub> )	ND	433.73	ND	ND	ND	ND	ND	ND	117.40	ND

ND = Not detected. The same below.

**Table 10 Hydrocarbon profile of nine varieties and one culture of rice in flowering phase**

Hydrocarbon	Pusa Basmati-1	Pusa Basmati-2511	Pusa Basmati-1077	Pusa Basmati-370	Pusa Sugandh-2	Karnal Local	Jaya	Pusa Basmati-1238	PRR-78	Culture No. 34
Favourable										
Henicosane (C <sub>21</sub> )	ND	ND	ND	ND	632.46	ND	ND	ND	1.77	ND
Docosane (C <sub>22</sub> )	ND	1 155.41	ND	ND	ND	ND	ND	ND	ND	ND
Tricosane (C <sub>23</sub> )	ND	ND	ND	ND	ND	ND	ND	1 484.20	0.49	ND
Pentacosane (C <sub>25</sub> )	8 497.44	2 750.00	21 330.00	841.00	241.16	227.48	ND	3 559.50	43.75	263.18
Hexacosane (C <sub>26</sub> )	938.33	ND	ND	ND	175.14	ND	ND	ND	0.02	266.77
Octacosane (C <sub>28</sub> )	ND	ND	24.78	ND	113.21	54.71	ND	ND	ND	ND
Nonacosane (C <sub>29</sub> )	3 714.67	395.35	ND	391.80	13 054.80	2 129.00	ND	ND	ND	364.00
Unfavorable										
Pentadecane (C <sub>15</sub> )	ND	0.02	1.28	ND	ND	ND	ND	0.24	0.65	0.03
Eicosane (C <sub>20</sub> )	ND	ND	6.43	ND	11.00	5.87	ND	ND	0.01	86.90
Tetracosane (C <sub>24</sub> )	ND	ND	71.77	ND	ND	ND	ND	ND	ND	ND
Others										
Decane (C <sub>10</sub> )	ND	0.014	ND	ND	ND	ND	0.019	0.08	0.21	ND
Undecane (C <sub>11</sub> )	ND	0.032	0.50	ND	ND	ND	ND	0.12	0.003	ND
Dodecane (C <sub>12</sub> )	ND	0.078	ND	ND	ND	ND	ND	0.23	0.005	ND
Tridecane (C <sub>13</sub> )	ND	0.013	ND	ND	ND	ND	ND	0.30	0.0004	ND
Tetradecane (C <sub>14</sub> )	ND	0.008	0.001	ND	ND	ND	0.0015	0.02	ND	0.05
Hexadecane (C <sub>16</sub> )	ND	0.013	0.007	ND	ND	ND	0.0018	0.03	0.06	0.41
Heptadecane (C <sub>17</sub> )	7 400	ND	0.109	ND	ND	ND	ND	0.07	1.94	0.91
Octadecane (C <sub>18</sub> )	ND	ND	ND	ND	ND	ND	ND	143.0	ND	4.39
Nonadecane (C <sub>19</sub> )	2 410.92	ND	ND	122.03	ND	ND	ND	412.10	ND	ND
Heptacosane (C <sub>27</sub> )	3 737.50	ND	ND	ND	ND	ND	ND	ND	793.4	504.40
triacontane (C <sub>30</sub> )	222.77	ND	ND	ND	3 642.40	488.81	ND	ND	ND	ND

elm leaf beetle *Xanthogaleruca luteola* (Mull.) and the eulophid egg parasitoid *Oomyzus galleruca* (Boy.) and (2) the pine (*Pinus sylvestris* L.), the pine saw fly *Diprion pini* (L.) and the eulophid egg parasitoid *Chrysonotomyia ruforum* (Krausse). Their studies revealed that jasmonic acid induced the plant to emit volatiles that attracted the parasitoids. In present study leaf extracts from variety Pusa Sugandh-2 elicited maximum response in vegetative phase for *T. japonicum* by way of mean PAI and mean percent parasitism whereas in case of *T. chilonis*, Culture No. 34 elicited maximum response as evidenced by mean PAI followed by Pusa Sugandh-2. Variety Pusa Sugandh-2 elicited maximum response from *T. chilonis* in vegetative phase by way of mean percent parasitism. Gas liquid chromatograph of Pusa Sugandh-2 in vegetative phase revealed the presence of two favourable hydrocarbons, pentacosane ( $C_{25}$ ), and nonacosane ( $C_{29}$ ). In the flowering phase variety Pusa Basmati-1 indexed highest mean PAI and mean percent parasitism for *T. japonicum*, whereas Culture No. 34 elicited maximum response followed by Pusa Basmati-1. Maximum mean percent parasitism was perceived in Pusa Basmati-1. Gas liquid chromatography studies of Pusa Basmati-1 in flowering phase showing the presence of pentacosane ( $C_{25}$ ), hexacosane ( $C_{26}$ ), nonacosane ( $C_{29}$ ), heptadecane ( $C_{17}$ ), nonadecane ( $C_{19}$ ), heptacosane ( $C_{27}$ ) and triacontane ( $C_{30}$ ), among these favourable hydrocarbon pentacosane ( $C_{25}$ ) was the highest. Madhu *et al.* (1997) compared the response of *T. japonicum* and *T. brasiliensis* to different saturated hydrocarbons including pentacosane ( $C_{25}$ ) and reported that in all concentrations tested, pentacosane ( $C_{25}$ ) elicited higher responses and parasitism from *T. japonicum*. Annadurai *et al.* (1992) had attributed the differential response from *T. chilonis* and *Chrysopa scelestes* Stephen to plant extracts from cotton varieties to the genetic differences of these varieties for their varied chemical profile. Manipulation of parasitoid behaviour through the exploitation of an array of synomonal hydrocarbons present in the varieties of rice can play a significant role in biological control programmes. Yadav *et al.* (2001, 2002) reported the presence of pentacosane ( $C_{25}$ ) in leaf extract of potato and soybean varieties, which elicited higher response from *T. exiguum* and classified pentacosane as favourable hydrocarbon for *T. exiguum*. Basit *et al.* (2001) studied the varietal preference of five ahu and five sali rice cultivars, viz., Govind, Annada, Jaya, Chilarai and Lachit, and Ranjit, Luit, Satyaranjan, Kushal, Monsaruber and Basundhara for parasitization by *T. chilonis* Ishii and found among the five ahu cultivars, the highest mean percentage parasitization (56%) was in Annada, while the lowest was in Chilarai (18%).

Among the sali cultivars Monsaruber showed highest parasitization (52.5%), while Basundhara showed the lowest (7.5%) parasitization. Taghadoshi (2003) studied the response of *T. chilonis* to leaf extracts from different varieties of cabbage and cauliflower and indicated that among these, cabbage variety Pusa Mukta and cauliflower variety Amazing showed maximum response which he attributed to the presence of pentacosane ( $C_{25}$ ) and nonacosane ( $C_{29}$ ) in these varieties. Lou *et al.* (2006) compared the volatiles of JA-treated plants of six rice varieties and then determined, in the laboratory and field, if they differed in attractiveness to *Anagrus nilaparavate* Pand *et* Wang, an egg parasitoid of rice plant hoppers. Analyses of volatiles revealed significant differences among varieties, both in total quantity and quality of the blends emitted. On the basis of these differences, the six varieties could be roughly divided into three groups. In a Y-tube olfactometer, female wasps preferred odors from two groups. These preferences corresponded to observed parasitism rates in a field experiment. A comparison of the volatiles with results from behavioral assays and field experiments indicates that the quality (composition) of the blends is more important for attraction than the total amount emitted. All these studies corroborate the present study that the favored response and parasitism by *T. japonicum* and *T. chilonis* in the egg cards treated with the leaf extract of Pusa Sugandh 2 and Pusa Basmati-1 may be due to the presence of these favourable hydrocarbons.

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## 9 个水稻栽培种和 1 个水稻组培种对稻螟赤眼蜂和赤眼卵蜂的互利作用

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**摘要:** 采用培养皿法对营养生长期和开花期的 9 个水稻栽培种 (Pusa Sugandh-2, Pusa Basmati-1, Pusa-2511, Pusa Basmati-370, Pusa-1077, Karnal Local, PRR-78, Jaya, Pusa-1238) 和 1 个组培种 (Culture No. 34) 的正己烷提取物进行了生测, 以调查它们对稻螟赤眼蜂 *Trichogramma japonicum* Ashmead 和赤眼卵蜂 *Trichogramma chilonis* (Ishii) 平均寄生活性指数 (PAI) 和平均寄生百分率的影响。将不同水稻品种的正己烷提取物进行气相-液相色谱, 来测定饱和碳氢化合物。其中, 营养生长期的 Pusa Sugandh-2 叶片提取物激发两种寄生蜂产生最大的反应, 平均寄生率最大。而开花期的 Pusa Basmati-1 使两种寄生蜂的平均寄生率最高。对营养生长阶段的叶片提取物进行的气相-液相色谱分析表明: Pusa Sugandh-2 含有 25 个碳原子 (C25) 和 29 个碳原子 (C29) 的 2 种化合物。对开花期的叶片提取物进行的气相-液相色谱分析也表明: Basmati-1 含有 25 个碳原子 (C25)、26 个碳原子 (C26) 和 29 个碳原子 (C29) 的 3 种化合物, 可激发寄生蜂产生最大的反应。

**关键词:** 稻螟赤眼蜂; 赤眼卵蜂; 互利素; 寄生蜂; 水稻

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